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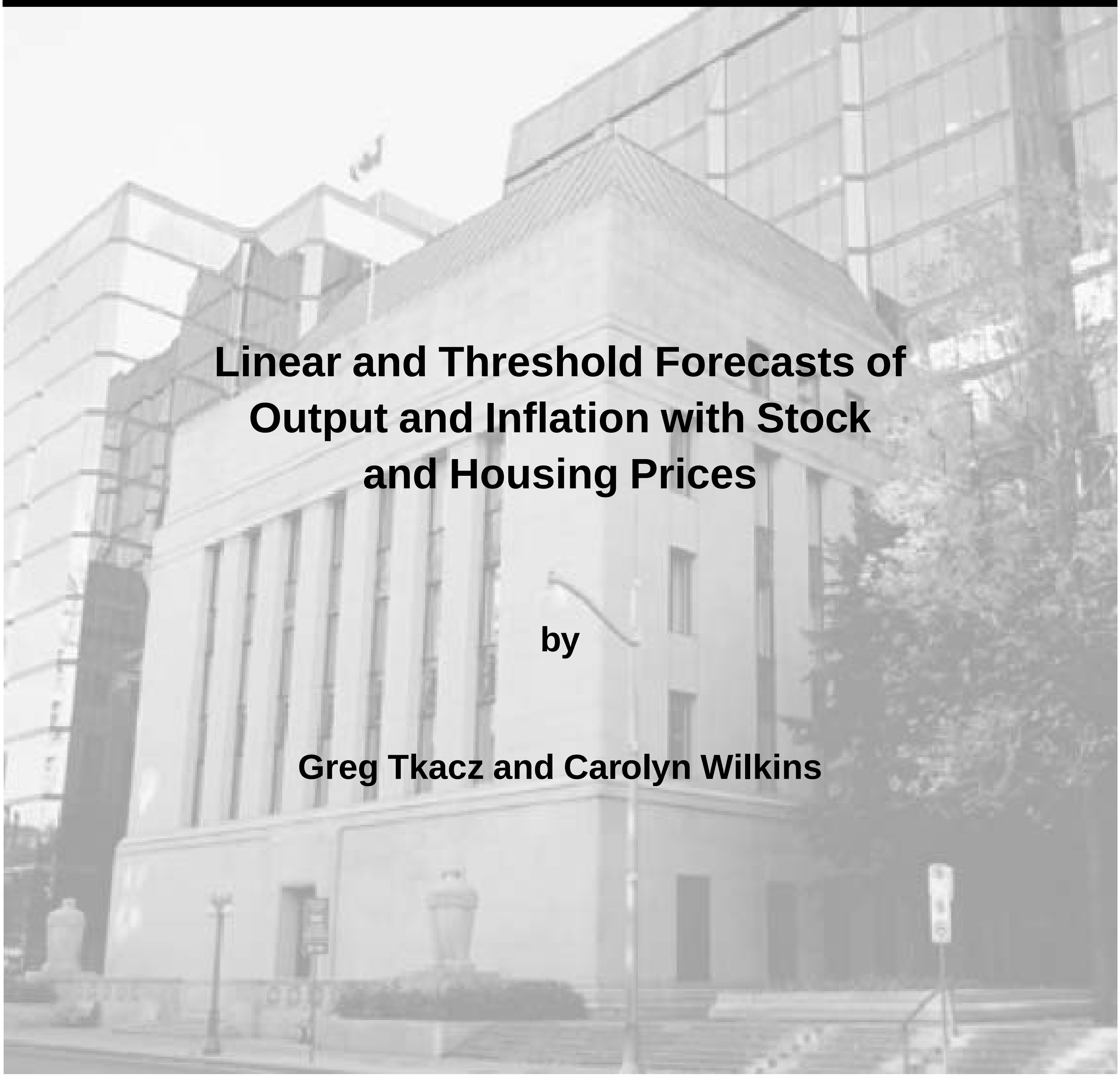

Linear and Threshold Forecasts of Output and Inflation with Stock and Housing Prices

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Abstract

The authors examine whether simple measures of Canadian equity and housing price misalignments contain leading information about output growth and inflation. Previous authors have found that the information content of asset prices in general, and equity and housing prices in particular, are unreliable in that they do not systematically predict future economic activity or inflation. However, earlier studies relied on simple linear relationships that would fail to pick up the potential non-linear effects of asset-price misalignments. The authors' results suggest that housing prices are useful for predicting GDP growth, even within a linear context. Moreover, both stock and housing prices can improve inflation forecasts, especially when using a threshold specification. These improvements in forecast performance are relative to the information contained in Phillips-curve type indicators for inflation and IS-curve type indicators for GDP growth.

JEL classification: C53, E4
Bank classification: Inflation and prices; Business fluctuations and cycles

Résumé

Les auteurs cherchent à savoir si des mesures simples des déséquilibres des prix des actions et de l'immobilier au Canada peuvent renseigner sur l'évolution future de l'inflation et de la croissance de la production. Selon certaines études, l'information contenue dans les prix des actifs, et notamment dans ceux des actions et de l'immobilier, n'est pas fiable, car elle ne permet pas de prévoir systématiquement le niveau de l'activité économique ou de l'inflation. Ces travaux s'appuyaient toutefois sur des relations linéaires simples, incapables de restituer les effets non linéaires des déséquilibres de prix. Les résultats présentés ici portent plutôt à croire que les prix de l'immobilier fournissent des données utiles pour la prévision de la croissance du PIB, même dans un cadre linéaire. Qui plus est, les prix des actions comme de l'immobilier permettent de mieux prédire l'inflation, surtout quand un seuil est spécifié. Les prévisions obtenues sont meilleures que celles élaborées à l'aide d'indicateurs du genre de ceux utilisés dans les courbes de Phillips (dans le cas de l'inflation) et dans les courbes IS (dans le cas de la croissance du PIB).

Classification JEL : C53, E4
Classification de la Banque : Inflation et prix; Cycles et fluctuations économiques

1. Introduction

Asset prices play an important role in the monetary policy transmission mechanism, because, among other things, they determine the value of wealth. Asset prices also determine the value of collateral posted by households and firms to obtain loans from banks. Finally, one important asset price, namely house prices, enters the calculation of the price of housing services in the consumer price index (CPI) and so affects inflation directly. These prices are also interesting to policy-makers because of their potential to signal future developments in key target variables, inflation and output. It is clear from Figures 1 and 2 that real stock prices and real housing prices in Canada, as in many countries, are highly correlated with the business cycle.

The issue of how to respond to movements in asset prices has gained prominence over the past decade, following an increasing number of asset-price booms and busts in many countries that have successfully achieved a low and stable inflation environment (Borio and White 2003; Goodhart 2003). The debate of how a central bank should best react to asset-prices is focused in large part on two issues: the ability of the monetary authority to identify asset-price misalignments, and the usefulness of asset prices and measures of price misalignments in signalling future economic developments of interest to the policy-maker.[1]

This paper seeks to inform the latter aspect of this debate by assessing whether asset prices and simple measures of price misalignments can predict GDP growth and inflation in Canada over horizons relevant for policy. We also test whether the relationships are characterized by non-linearities, as one would expect in an economy with financial frictions, using a two-regime threshold model.

There are many important asset prices in the economy, but this paper will focus on equity and housing prices. These prices are worth special attention given their large share in household and business balance sheets and the fact that these asset prices have historically been prone to episodes of volatility and misalignments (i.e., bubbles[2]). The National Balance Sheet data

[1] See Borio and White (2003) and Bean (2003) for excellent reviews of the issues. See Selody and Wilkins (2004) for a review of the issues from a Canadian perspective.

[2] The terms misalignment and bubble are used interchangeably in reference to any deviation of an asset price from its fundamental value.

indicate that household assets in Canada are heavily weighted towards real assets such as housing, accounting for around 46 per cent of household wealth in 2003 (Figure 3). Financial assets such as life insurance, pensions, equities, and mutual funds make up the balance.[3] Once liabilities are accounted for and adjustments are made to estimate the market value of assets Macklem (1994),[4] however, the stock market accounts for around half of net non-human wealth (Figure 4). Exchange rates are also subject to this kind of volatility but are not considered in this paper.

Interpreting the evidence as to whether asset prices are useful indicators for monetary policy leaves ample room for debate. On the one hand, Borio and Lowe (2004) find that simple measures of misalignment in credit markets are useful indicators of economic downturns and banking stress. On the other hand, Stock and Watson (2003) find that, among the G-7 countries, asset prices in general, and equity and housing prices in particular, are unreliable indicators for monetary policy. These authors do not rule out the possibility that a stable non-linear relationship between asset prices and economic activity exists, although they do not test for this. Some promising evidence exists for the United States showing non-linear relationships between economic growth and measures of misalignments in equity markets (Chauvet 1998–99; Bradley and Jansen 2004).

The remainder of this paper is organized as follows. Section 2 further articulates the research question in the context of the relevant literature. Sections 3 and 4 present the empirical methods and data. The empirical results from the linear and non-linear analyses are presented in section 5. Section 6 concludes and suggests avenues for future research.

2. Related Literature

If fluctuations in asset prices contain leading information about GDP and/or inflation, then they should be included in the information set considered by policy-makers. In theory, if asset markets are informationally efficient and market participants are rational, then asset prices

[3] These data, although used extensively in analysis and international comparisons, do not properly account for changes in the market value of these assets over time. As a result, the share of a particular asset is likely (under-) overstated when its relative price is (rising) falling.

[4] The market value of equity is estimated by augmenting the book value by the increase in the Toronto Stock Exchange (TSX). A similar procedure is applied to housing assets using the MLS price index.

should reflect relevant information existing elsewhere about expected future events (Smith 1999). This would be true, for instance, if equity prices were the discounted present value of future dividends and housing prices were the present discounted value of imputed rents. In practice, however, financial markets are incomplete, information is costly to acquire, and not all movements in asset prices reflect changes in fundamentals such as rational estimates of discount rates and future dividend streams. Therefore, asset-price movements may send signals about future economic developments that are not contained in standard indicators used by policy-makers. This may be especially true when asset prices are driven by non-fundamental factors or irrational behaviours.[5]

For many countries, the empirical evidence suggests that the information content of asset prices in general, and equity and housing prices in particular, is unreliable or underwhelming.[6] Stock and Watson (2003) assess with linear methods the relative information content of 38 indicators from seven developed economies including Canada, finding that the predictive power of asset prices for output growth and inflation varies between countries and tends to be unstable over time.

Other researchers have found that useful information for monetary policy can be extracted from housing and equity prices using linear methods in some countries. For example, Goodhart and Hofmann (2000) find that housing prices have leading-indicator properties for inflation in 12 countries, although Cecchetti et al. (2000) and Filardo (2001) show that the inclusion of housing prices does not improve inflation forecasts in an economically significant manner. Work on a financial conditions index (FCI) for Canada, which includes housing and equity prices, provides some leading information for output at some horizons, but not for inflation (Gauthier, Graham, and Liu 2004). While this work suggests a promising avenue for future research, overall the evidence suggests that indicator models that include these types of asset prices should not receive a large weight in policy decisions.

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[5] This paper does not address the question of why asset prices may deviate from fundamentals. See Selody and Wilkins (2004) for a brief general discussion of the literature on bubbles, and Bikhchandani and Sharma (2000) for an excellent review of financial market herding models.

[6] Performance measures are typically based on comparisons of out-of-sample forecasts at different horizons relative to a simple autoregressive model.

A possible explanation for the disappointing performance of asset prices as indicators may be that linear, reduced-form techniques are inadequate for capturing the underlying relationship between asset prices and the real economy. Gilchrist and Leahy (2002), among others, suggest that movements in asset prices should be evaluated only in structural-behavioural models that are explicit about their causal or structural relationship to economic activity.[7] Alternatively, Stock and Watson (2003) suggest the possibility that a stable non-linear relationship exists between asset prices and economic activity, although they do not test this hypothesis.[8]

One reason why asset prices may exhibit a non-linear relationship with real activity is that financial frictions cause agents to face financing constraints. As net wealth increases with a rise in asset prices, these financing constraints are relaxed so that more projects can be financed. This effect diminishes to zero, however, as asset prices rise by enough to ensure that all agents are no longer constrained (Kiyotaki and Moore 1997). A related explanation is that when prospects for future productivity growth rise, the value of the firm increases and financing constraints are relaxed, even if the current growth rate is unchanged (Jermann and Quadrini 2002). Alternatively, the relationship between asset prices and economic activity may be non-linear if asset-price misalignments, or bubbles, have different empirical properties than asset-price fluctuations driven by fundamentals. This may be because the underlying behaviours that drive asset-price bubbles are different from those that drive asset-price fundamentals (Filardo 2001). For example, bubbles may reflect periods where expectations become extrapolative, while non-bubble periods are characterized by mean-reverting expectations.

There exists some empirical evidence of non-linear relationships between economic growth and measures of misalignments in asset prices, although this literature is in its early days and tends to focus more on equity markets than on housing markets. For example, Bradley and Jansen (2004) study whether unusual changes in stock returns (and excess returns) have any information for U.S. output over the 1934 to 2002 period. The authors reject linearity and find interesting

[7] The authors refer to arguments made by Woodford (1994) that poor forecasting performance of an indicator may be expected if policy-makers use this information and respond to it.

[8] An alternative reason for the instability may be the changing nature of financial structures within countries across time, or the differing types of financial structures across countries, although this latter explanation does not seem to be validated by an investigation of the data for 29 OECD countries (Djoudad, Selody, and Wilkins 2005).

threshold effects, although out-of-sample forecasting is poor relative to the linear model, due to overfitting. Chauvet (1998-99) tests numerous stock market factors (e.g., excess stock returns, S&P500 dividend yield) as predictors of business cycle turning points, and finds that stock market factors perform better than typical business cycle indicators, even in real time. Borio and Lowe (2003) find a significant relationship between several measures of financial imbalances and banking distress, as well output and inflation declines up to four years ahead.

Tkacz (2001) finds improvements in forecasting Canadian GDP using neural network models, and Tkacz (2004) finds evidence of threshold effects in the relationship between the yield spread and inflation in the United States and Canada. Galbraith and Tkacz (2000) find some evidence of non-linear relationships between the term spread and output for both Canada and the United States, but not for other G-7 countries. Given the prevalence of non-linearities between the term spread and either output or inflation for both the United States and Canada, we feel that investigating the existence of such non-linearities between these variables and other asset prices may yield some valuable insights. Asset-price bubbles, no matter how defined, would be best captured with non-linear methods, so the threshold models that we present below could be viewed as proxies for the level at which an asset price begins to exert additional pressure on the economy beyond what would be considered normal given the underlying economic fundamentals.

This paper seeks to add to this literature by looking first at the predictive power for Canadian GDP and inflation of equity and housing prices, and simple measures of misalignments of these prices, and then testing for non-linearity in the form of threshold effects in these relationships.

3. Empirical Methods

The methodology is designed to answer the following questions: (1) Do measures of asset prices and asset-price misalignments have useful information for monetary policy? (2) Is this information better extracted using a linear model or a model with threshold effects?

In order to answer these questions we examine whether asset prices and simple measures of asset-price misalignments can help predict output and inflation over forecast horizons spanning one to 16 quarters using linear models. This assessment is based on out-of-sample criteria. We then test estimate two-regime threshold models, which represent a simple yet effective way to capture potential non-linearities in the relationships between asset prices and macroeconomic variables. The forecasts emanating from the threshold models are then assessed relative to those of the linear models.

3.1 Linear models

The linear approach assumes that the target variables are linear functions of the indicator variables, according to the following general equation of the Stock and Watson (2003) type:

$$y_{k,t} = a + b y_{k,t-k} + g X_{k,t-k} + x_t \quad . \tag{1}$$

$y_{k,t}$ is the target variable of interest in cumulative growth-rate terms (annual rates) over k periods, where k = 1, 4, 8, 12, and 16 quarters. Lagged values of y_k are included as explanatory variables to account for serial correlation, and to avoid misspecification problems. $X_{k,t-k}$ is a vector of indicator variables of interest.

The explanatory variables for the benchmark CPI inflation model are lagged inflation (to capture the persistence in inflation, especially in Canada) augmented by the output gap (a pseudo Phillips curve), while for real output growth we use lagged output augmented by the output gap and the term spread (a pseudo-IS curve). These benchmarks allow us to test the value-added of the asset-price variables relative to other variables typically used by policy-makers. This puts the bar higher than it would be under the simple AR(1) benchmark typically found in the literature.

Equation (1) is estimated first by adding each asset-price measure to the benchmarks, and then in combinations. These augmented equations are then compared with the benchmarks using tests of the equality of mean squared errors (MSEs). The out-of-sample forecasts are constructed by estimating the model up to period t (1999Q4) and then producing forecasts for period $t+k$; the sample is then updated so that the model is re-estimated using data up to $t+1$, and a forecast is then produced for $t+k+1$. We continue in this fashion until out-of-sample forecasts are generated for the full out-of-sample period 2000Q1 to 2004Q4.

3.2 Threshold models

We next estimate a model that allows for asymmetry in the form of a threshold effect of asset prices on output growth and inflation. As such, the relationship between asset prices and macro variables will be dependent either on the magnitude of the deviation of an asset price from its fundamental value, or on the magnitude of the growth rate of the asset price. The specific model chosen is a two-regime threshold model, which has the advantage of a fairly general specification while still allowing the parameters to be observed. Experiments with alternative non-linear specifications are left to future work. The models take the form

$$y_{k,t} = a^1 + b^1 y_{k,t-k} + g^1 X_{k,t-k} + d^1 z_{k,t-k} + x_t \qquad \text{for } z_{k,t-k} \leq t\ , \tag{2}$$

$$y_{k,t} = a^2 + b^2 y_{k,t-k} + g^2 X_{k,t-k} + d^2 z_{k,t-k} + x_t \qquad \text{for } z_{k,t-k} > t\ , \tag{3}$$

where z is some variable extracted from the vector X, usually representing stock or housing prices, and t represents the level of z that triggers a regime change. Superscripts denote the values taken in regimes 1 and 2, respectively.

The threshold level is unknown a priori, so we perform a grid search over 200 different values of the threshold variable in an attempt to maximize the probability of locating a significant threshold, should it indeed exist. Consistent with Andrews (1993), we trim the grid by 15 per cent at each end in order to minimize the effects of outliers. To conduct inference on the significance of the threshold, we use the bootstrap procedure proposed by Hansen (1996). The estimated thresholds for each model, along with their accompanying *p*-values, are computed using 2000 bootstrap replications. Similar strategies were employed by Galbraith and Tkacz (2000) and Tkacz (2004) for mapping the relationship between the term spread and either GDP growth or inflation. Note that for some models (7 through 10) we have two candidate threshold variables, and so we test the significance of each in turn. This therefore yields 13 different models for each horizon *k*.

To estimate the parameters of the threshold model (2)-(3), we follow Hansen (2000), who derives an approximation of the asymptotic distribution of the least-squares estimator of the threshold parameter $\hat{t}$. To understand how the parameters are estimated, we introduce an indicator function *d* and can rewrite equations (2) and (3) as a single equation:

$$y_{k,t} = a^2 + b^2 y_{k,t-k} + g^2 X_{k,t-k} + d^2 z_{k,t-k} + Ad + Bdy_{k,t-k} + CdX_{k,t-k} + Ddz_{k,t-k} + x_t \,, \tag{4}$$

where

$$d = \begin{cases} 1 & z_{k,t-k} \le t \\ 0 & z_{k,t-k} > t \end{cases},$$

$a^2 + A = a^1$, $b^2 + B = b^1$, $g^2 + C = g^1$, and $d^2 + D = d^1$.

By assuming that $\hat{t}$ is bounded by the largest and smallest values of the asset-price variables, we can estimate the parameters in (4) by least squares conditional on a given value of $\hat{t}$. By iterating through the possible values of $\hat{t}$ in the range of available asset-price growth rates or deviations from equilibrium, we select the $\hat{t}$ that minimizes the sum of squared residuals in (4) and are therefore not constrained by the trimming used to conduct inference on the existence of a threshold.

To perform out-of-sample forecasts using the threshold model, we estimate the model, both the parameters, and the threshold, up to period *t* (1999Q4), and then produce forecasts for period *t*+*k*; the sample is then updated so that the model is re-estimated using data up to *t*+1, and a forecast is then produced for *t*+*k*+1. We continue in this fashion until out-of-sample forecasts are generated for the full period 2000Q1 to 2004Q4.

3.3 Forecast evaluation

Our objective, in the first instance, is to determine whether asset prices are useful in predicting output and inflation, and in the second instance we wish to determine whether the relationship between asset prices and either output or inflation can be more effectively modelled using a non-linear threshold model rather than a linear model. Several forecast-encompassing tests have been developed to determine whether one model produces statistically superior forecasts relative to another. Such tests have been proposed by, for example, Diebold and Mariano (1995), West (1996, 2001a, 2001b), and Harvey, Leybourne, and Newbold (1997, 1998). A crucial requirement of these tests is that the models being compared be non-nested. If they are nested, then under the null hypothesis the forecast errors will be asymptotically the same and therefore perfectly correlated, rendering inference imprecise.

More recently, Clark and McCracken (2001) and McCracken (2004) have developed approaches that can, respectively, test for encompassing forecasts between nested models, and test for equality of MSEs for nested models. In our study we perform two different forecast-encompassing tests from Clark and McCracken (2001), and two different tests of the equality of MSEs from McCracken (2004). However, since the results of all four tests are very similar, we choose to present the results of only one of the equality of MSE tests.

Let d_{t+k} denote the difference between the squared forecast errors at the $t+k$ of the base-case model (e.g., the model without asset prices) and the alternative model (e.g., the model augmented with one or more asset prices):

$$d_{t+k} = \hat{e}^2_{1,t+k} - \hat{e}^2_{2,t+k} \,. \tag{5}$$

With n forecast periods, the statistic for testing the equality of MSEs between the base-case and alternative model is computed as

$$MSE - F = n \sum \frac{n^{-1} \sum_{t=R-k}^{T} (\hat{e}^2_{1,t+k} - \hat{e}^2_{2,t+k})}{n^{-1} \sum_{t=R-k}^{T} \hat{e}^2_{2,t+k}} \,, \tag{6}$$

where R represents the first out-of-sample forecast period (2000Q1). Intuitively, note that the numerator represents the difference in MSEs between the base-case and alternative model, and the denominator represents the MSE of the alternative. If both models produce equally accurate forecasts, then the numerator and test statistic are zero; if the base-case model has a lower MSE, then the statistic will be negative, and it will be positive if the alternative has a lower MSE. The distribution is non-standard due to the fact that the models are nested, and so we use the critical values computed by McCracken (2004). Results reported by McCracken show that this test has good size and power for sample sizes as small as 50. Our own application has a sample size of 20, and thus size and power could be an issue, so some caution should be used when interpreting results for some MSEs that may be particularly close. We will highlight cases at the margin that may produce different conclusions among the four tests that we conduct.

4. Data

This study uses quarterly Canadian data over the period 1981Q1 to 2004Q4 for real GDP, consumer price inflation (all items), the TSX index, and the new housing price index. Equity and housing prices are deflated by the CPI. These variables are transformed into cumulative, annualized growth rates over the k horizons. The term spread is defined as the difference between the 10-year-and-over government bond yield less the 90-day commercial paper rate. The output gap is taken from the Quarterly Projection Model (QPM) of the Bank of Canada (see, e.g., Coletti et al. 1996).[9]

The measures of misalignment in asset prices are proxied by deviation from trend as measured by a one-sided Hodrick-Prescott (HP) filter of the levels of the TSX and the new housing price index. The one-sided filter is chosen to proxy information that would be available in real time. An additional measure of misalignment in equity prices is taken from Gauthier and Li (2004); see Figure 5.[10] Details of the Gauthier and Li measure are provided in the appendix. Both this measure and the output-gap measure have the disadvantage of using ex post information. In the case of the output gap, however, this makes it more difficult for asset prices to have significant value-added.

Any definition of an asset-price misalignment is highly subjective, since there are many different yet legitimate ways to think about fundamental value. Taking a mechanical view of fundamentals is popular in the empirical literature (e.g., Helbling and Terrones 2003; Detken and Smets 2003), mainly because it is relatively straightforward to apply to large data sets and does not rely on any particular theory. Details of the mechanics differ between studies, but the premise is the same: asset-price fundamentals are captured by a slow-moving trend line through the timeline mapped

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[9] The same equations were estimated using CPIX, with generally poorer results than with CPI. The existing price index was also tested, but not reported here because of the short sample size.

[10] All series used in the empirical analysis appear to be stationary by at least one standard unit-root test.

out by actual asset prices. For example, as in this study, Detken and Smets (2003) use a one-sided HP filter to determine fundamental values of the asset prices in their study, which includes housing and stock prices.

The disadvantage of a mechanical approach, like the one employed in this study, is that there is no explicit link between the trend line (i.e., the fundamental value) and the underlying economic forces that may be responsible for the movements in asset prices, and so the estimate of the fundamental value is ad hoc. Defining an asset-price bubble without any reference to a structural model that delineates the underlying behaviours that cause the bubble is somewhat problematic. The problem arises because any evidence of a bubble can be attributed to a bad estimate of fundamental value; e.g., attributed to variables that are unobserved by researchers and therefore missing from the model of fundamental value (Hamilton and Whiteman 1985).

An alternative mechanical definition of asset-price bubbles is given by Kindleberger (1987), and can be found in the *New Palgrave Dictionary of Money and Finance*. It is based on the rate of change of an asset price, rather than its deviation from the fundamental value: a bubble is "a sharp rise in the price of an asset or a range of assets in a continuous process, with the initial rise generating expectations of further rises and attracting new buyers—generally speculators—interested in profits from trading in the asset rather than its use or earning capacity." Case, Quigley, and Shiller (2003) find evidence in the U.S. housing market of this type of extrapolative expectations.[11] Under this definition, the real growth rates in asset prices could also be considered to capture a bubble component.[12] This approach has the advantage of relying only on observed data, although it may be capturing effects other than those coming from bubbles.

A method that does link the fundamental value to macroeconomic variables is to use a macroeconomic model to identify the long-run determinants of an asset price such as equity or housing prices. The fundamental value in this approach is defined as the accumulation of

[11] In a survey of the expected housing price increase over the next decade by U.S. house buyers, the authors observe that even after the recent long boom in U.S. house prices buyers are still expecting double-digit average annual price increases over the next decade.

[12] For example, Bordo and Jeanne (2002) use this type of definition, basing their measures of asset-price booms and busts on abnormal growth rates, rather than on the percentage deviation from a slow-moving trend line that represents fundamentals.

permanent shocks to asset prices (Dupuis and Tessier 2003; Gauthier and Li 2004).[13] We use the measure of misalignment for the TSX from the bonds, equity, and money (BEAM) model in Gauthier and Li (2004). Unfortunately, no similar measure exists for house prices in Canada.[14] While this approach to determining fundamental value has the appeal of being linked to the macro economy, the link is reduced-form without macroeconomic behavioural foundations. It also uses econometric estimates rather than arbitrary exogenous assumptions about the future path of revenue streams and discount rates to determine fundamental values, as is the case in standard valuation models. The weakness of this approach is that there is no guarantee that the macroeconomic variables identified in the cointegrating vector are in fact linked to the future revenue stream of the asset or to future discount rates.

5. Empirical Results

5.1 Linear models

In Tables 1 and 2 we present the root mean squared errors (RMSE) of the various linear models for the forecast exercises for GDP growth and inflation, respectively. The magnitudes of these statistics show the average forecast error that one would achieve at the different forecast horizons. One, two, or three asterisks beside the RMSE of any alternative model (models 2 through 10) indicate that the MSE of the alternative is significantly lower than the MSE of the base-case model at the 90 per cent, 95 per cent, and 99 per cent significance levels, respectively.

<u>GDP growth:</u>

A notable finding is that all models that include the growth rate of new house prices result in forecast improvements relative to the base-case model for at least some horizons (Table 1). Model 5, which augments the base-case model with housing price growth, produces some of the most notable forecast improvements. At the four-quarter horizon, the RMSE falls to 1.37 from 1.92 relative to the base case, whereas at the eight-quarter horizon we find that the RMSE falls to 0.84 from 1.86. This means that by augmenting a simple model with the growth rate of housing

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[13] Alternatively, the fundamental value could be defined as the price of the asset predicted by the cointegrating vector, so that the asset-price misalignment is the deviation of the actual asset price from the price predicted by the cointegrating vector.

[14] Traclet (2005) estimates measures of misalignment in regional housing prices in Canada, but unfortunately these are based on growth rates and have only very short sample lengths.

prices, one could have reduced the forecast error by, on average, one per cent at the eight-quarter horizon over this period.

Stock prices, meanwhile, result in less notable improvements. The stock price misalignment measures, constructed using either the one-sided HP filter or BEAM, aid little in reducing forecast errors. The one exception is Model 3, which augments the base-case model with the growth rate of real stock prices. At the longer 12- and 16-quarter horizons, we notice that the RMSE drops by as much as 0.35.

<u>CPI inflation:</u>

For inflation (Table 2), few of the augmented models yield significant forecast improvements. The benchmark model for this variable, which includes lagged inflation and the output gap, sets a high performance standard. Given that inflation expectations have been strongly anchored for several years due to the advent of formal inflation targets in the early 1990s, the inflation rate has been low and stable, with the consequence that lagged inflation contains a great deal of information regarding future inflation.

Compared with the output models of Table 1, asset prices yield few improvements to inflation forecasts within a linear context. The exception would appear to be models that include the filtered new house price gap (Models 6, 8, and 9), where some forecast improvements are achieved at the 12- and 16-quarter horizons. Model 6, which augments the base-case model with the filtered house price gap, lowers the RMSE of the base-case model by a full quarter of a per cent at the 16-quarter horizon.

In short, we find that the growth rate of housing prices yields significant forecast improvements for output, and that the measure of misalignment of house prices improves inflation forecasts, albeit at longer horizons.

5.2 Threshold models

Tables 3 and 4 present the output and inflation forecast results for the threshold models. The base-case models are as before, except that we allow for a threshold effect on the term spread for the output-growth model, and on the output gap for the inflation model. The thresholds are estimated using the method described in section 3.2, and are updated as each forecast is produced.

GDP growth:

For output growth (Table 3), we again find that models that include the growth rate of real house prices (Models 5, 8, and 9) produce some significantly lower forecast errors relative to the base-case model, especially at the eight-quarter horizon. For Model 5 at $k = 8$, the RMSE is 0.55, compared with 0.81 for the base-case model. Models containing the BEAM stock price gap (Models 3, 7, and 9) also yield some significantly lower errors at some horizons.

CPI inflation:

For inflation (Table 4), it is somewhat striking that nearly all models yield improved forecasts relative to the base case at the eight-quarter horizon. The model that incorporates the greatest number of asset prices (Model 9) yields the lowest forecast errors at horizons one, four, and eight. The performance is especially notable at the eight-quarter horizon, where the forecast error averages only 0.26 per period, which is quite remarkable for a two-year forecast.

5.3 Comparing linear and threshold results

We have so far found that asset prices can improve forecasts of output and inflation over some horizons. In this section we focus on determining whether such a relationship should be best modelled using a linear or threshold specification.

In Table 5 we test the equality of the MSEs of the linear models against the corresponding threshold models for GDP growth. Note that we are once again testing two nested models, since the linear specification is nested within the alternative threshold specification. The numbers in each cell correspond to the RMSE of the linear model (taken from Table 1) and the corresponding threshold model (from Table 3). Asterisks again denote various significance levels when applying the MSE-F test.

Our primary observation is that the threshold models dominate the linear specifications in our forecasting exercises for almost all specifications at the one-, four-, and eight-quarter horizons. In short, this leads us to conclude that, if one wishes to extract relevant information for future

GDP growth from asset prices, then exploiting non-linearities in the short- to medium-run horizons should be promising. However, we should recall that, relative to the benchmark model, the growth rate of house prices seems to be contributing the most to forecast improvements. Future work could explore alternative non-linear specifications to determine which specification would be most suitable for modelling this relationship.

For inflation (Table 6), we find that the non-linear specifications tend to dominate the linear specifications at most horizons. Some notable improvements occur when the base-case model is augmented with asset prices in growth rate and deviations from equilibrium (Model 9). When we account for thresholds, the RMSE for this model drops from 1.03 to 0.26. These results suggest that if asset prices contain information about future inflation expectations, then the manner in which such expectations are formed will likely depend on the level or growth rate of the underlying asset.

To better understand the significance that thresholds have for the underlying estimated relationships, we present in Tables 7 and 8 the estimated parameters of the best output and inflation-forecasting models at the eight-quarter horizon. For output, we find that a threshold exists when the growth rate of new house prices is 1.9 per cent. The differences in the estimated parameters below and above this threshold are rather striking, since the magnitude and signs of some parameters change drastically. It is also interesting that the house price parameter is significantly negative in both regimes, although the magnitude of this parameter is more than six times larger in the high house price growth regime. However, it should be noted that over our entire sample, fewer than 20 per cent of observations occur in regime 2.

For inflation, we find that a significant threshold exists when the house price gap is at 0.012. The overall in-sample fit of the threshold model is superior, and the four asset-price variables are all statistically significant in the low house price gap regime. Above this level, the house price growth parameter remains relatively constant, although the house price gap parameter drops from 25 to 7, and the stock price gap becomes positively significant. This means that when house prices are above their long-run trend, which could be weak evidence of a housing bubble, then a widening of stock prices from their fundamental levels will have a positive impact on inflation expectations. In short, if we were in such a regime at the end of 2004, as suggested by Figure 5, and if stock prices rise by 10 per cent relative to their long-run trend, then we would expect the inflation rate over the next two years to increase by 0.2 per cent. By contrast, if one used a linear model, one would conclude that a 10 per cent increase in the stock price gap would have almost no impact on the inflation rate.

6. Concluding Remarks

Overall, we find that asset prices can be of use in predicting output and inflation, although the model specification, and the optimal forecast horizon, is different for both output and inflation.

For output, we find that the growth rate of house prices assists in reducing forecast errors, especially when trying to forecast output growth one to three years into the future. The threshold specifications aid in reducing forecast errors relative to the benchmark model, especially at the eight-quarter forecast horizon. However, these reductions are not overly substantial from a macroeconomic perspective.

For inflation, we find that asset prices generally have little value-added within linear specifications, except at the longest forecast horizons. More generally, substantial reductions in forecast errors can be attained using threshold models. Given the relative stability of Canadian inflation over the past several years, an average reduction in forecast errors of about one quarter of one per cent at the eight-quarter horizon is non-negligible. Both housing and stock prices, measured in growth rates or as deviations from long-run trends, contribute towards the improved forecast performance.

Our findings are generally consistent with the existing empirical evidence cited earlier. Future work should focus on testing the robustness of the results to a wider range of measures of asset-price misalignments, real-time estimates of the output gap and other variables, alternative non-linear specifications, and, where possible, different forecasting periods. It would also be interesting to test the relationships between asset prices, inflation, and real activity for other industrialized countries.

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Table 1: GDP Root Mean-Squared Errors, Linear Models

Model	Regressors	$k = 1$	$k = 4$	$k = 8$	$k = 12$	$k = 16$
Base case						
1.	• Lagged Output • Output Gap (QPM) • Term Spread	1.64	1.92	1.86	1.14	1.39
Alternatives Relative to Base case: Additional Regressors						
2.	• Stock Prices (Real Growth)	1.62	1.94	1.87	0.97***	1.04***
3.	• Stock Price Gap (BEAM)	1.74	1.84**	1.76**	1.54	1.84
4.	• Stock Price Gap (Filter)	1.66	1.99	2.02	1.15	1.40
5.	• New House Prices (Real Growth)	1.61*	1.37***	0.84***	0.63***	1.31**
6.	• New House Price Gap (Filter)	1.65	2.15	2.00	1.13	1.46
7.	• Stock Prices (Real Growth) • Stock Price Gap (BEAM)	1.70	1.96	1.86	1.36	1.40
8.	• New House Prices (Real Growth) • New House Price Gap (Filter)	1.64	1.38***	1.01***	0.62***	1.27***
9.	• New House Prices (Real Growth) • New House Price Gap (Filter) • Stock Prices (Real Growth) • Stock Price Gap (BEAM)	1.65	1.61***	1.01***	0.59***	1.44
10.	• New House Prices (Real Growth) • Stock Prices (Real Growth)	1.58*	1.41***	1.02***	0.60***	1.38

Notes: Each cell presents the RMSE for the given model at the specified horizon. * indicates that the RMSE of the alternative model (Models 2 through 9) is significantly lower than the RMSE of the base-case model (Model 1) at the 10 per cent level; ** at the 5 per cent level; *** at the 1 per cent level.

Table 2: Inflation Root Mean-Squared Errors, Linear Models

Model	Regressors	$k = 1$	$k = 4$	$k = 8$	$k = 12$	$k = 16$
Base case						
1.	• Lagged Inflation • Output Gap (QPM)	2.86	1.32	0.53	0.47	0.58
Alternatives Relative to Base case: Additional Regressors						
2.	• Stock Prices (Real Growth)	2.96	1.33	1.03	0.87	1.45
3.	• Stock Price Gap (BEAM)	2.92	1.30	0.66	0.87	0.77
4.	• Stock Price Gap (Filter)	3.03	1.35	0.65	0.50	0.69
5.	• New House Prices (Real Growth)	2.85	1.50	0.88	0.71	2.20
6.	• New House Price Gap (Filter)	2.86	1.35	0.57	0.41**	0.32***
7.	• Stock Prices (Real Growth) • Stock Price Gap (BEAM)	3.00	1.31	1.12	1.13	1.49
8.	• New House Prices (Real Growth) • New House Price Gap (Filter)	2.85	1.49	0.78	0.45**	0.86
9.	• New House Prices (Real Growth) • New House Price Gap (Filter) • Stock Prices (Real Growth) • Stock Price Gap (BEAM)	3.05	1.66	1.03	0.74	0.55**
10.	• New House Prices (Real Growth) • Stock Prices (Real Growth)	2.95	1.50	0.90	0.64	1.73

Note: See notes to Table 1.

Table 3: GDP Root Mean-Squared Errors, Threshold Models

Model	Regressors	*k* = 1	*k* = 4	*k* = 8	*k* = 12	*k* = 16
Base case						
1.	• Lagged Output • Output Gap (QPM) • Term Spread	1.53	1.04	0.81	1.51	1.61
Alternatives Relative to Base case: Additional Regressors						
2.	• Stock Prices (Real Growth)	1.61	1.40	1.23	1.62	2.37
3.	• Stock Price Gap (BEAM)	1.60	1.08	1.37	0.97***	2.12
4.	• Stock Price Gap (Filter)	1.54	1.58	1.00	1.64	2.45
5.	• New House Prices (Real Growth)	1.54	1.44	0.55***	0.97***	2.06
6.	• New House Price Gap (Filter)	1.45**	1.10	0.79*	1.94	1.70
7.	• Stock Prices (Real Growth) • Stock Price Gap (BEAM)	1.47** 1.53	1.19 0.91***	1.13 1.14	1.60 1.44**	2.19 2.11
8.	• New House Prices (Real Growth) • New House Price Gap (Filter)	1.64 1.47**	1.38 1.26	0.68*** 0.62***	0.96*** 2.06	1.90 1.55*
9.	• New House Prices (Real Growth) • New House Price Gap (Filter) • Stock Prices (Real Growth) • Stock Price Gap (BEAM)	1.44** 1.58	1.17 1.02	0.70*** 0.60***	1.67 1.77	1.76 2.03
10.	• New House Prices (Real Growth) • Stock Prices (Real Growth)	1.59 1.59	1.54 1.36	0.82 1.08	1.20*** 1.67	2.12 2.34

Note: See notes to Table 1.

Table 4: Inflation Root Mean-Squared Errors, Threshold Models

Model	Regressors	$k = 1$	$k = 4$	$k = 8$	$k = 12$	$k = 16$
Base case						
1.	• Lagged Inflation • Output Gap (QPM)	2.23	1.17	0.65	0.59	1.02
Alternatives Relative to Base case: Additional Regressors						
2.	• Stock Prices (Real Growth)	2.40	1.30	0.53***	0.95	1.31
3.	• Stock Price Gap (BEAM)	2.63	1.24	0.54***	0.81	1.10
4.	• Stock Price Gap (Filter)	2.43	1.34	0.57***	0.80	0.84***
5.	• New House Prices (Real Growth)	2.34	1.39	0.56***	0.78	0.89***
6.	• New House Price Gap (Filter)	2.72	1.20	0.46***	0.58	1.07
7.	• Stock Prices (Real Growth) • Stock Price Gap (BEAM)	2.30 2.62	1.16 1.23	0.72 0.65	0.95 0.88	1.37 1.26
8.	• New House Prices (Real Growth) • New House Price Gap (Filter)	2.34 2.54	1.29 1.11**	0.52*** 0.39***	0.96 0.60	0.80*** 1.05
9.	• New House Prices (Real Growth) • New House Price Gap (Filter) • Stock Prices (Real Growth) • Stock Price Gap (BEAM)	1.97*** 2.56	1.00*** 1.10**	0.26*** 0.39***	0.64 1.19	0.85*** 1.10
10.	• New House Prices (Real Growth) • Stock Prices (Real Growth)	2.32 2.54	1.47 1.41	0.54*** 0.50***	0.82 0.91	0.85*** 0.83***

Note: See notes to Table 1.

Table 5: GDP Root Mean-Squared Errors, Linear vs. Threshold Models

Model	Regressors	*k* = 1	*k* = 4	*k* = 8	*k* = 12	*k* = 16
Base case						
1.	• Lagged Output • Output Gap (QPM) • Term Spread	1.64 (1.53***)	1.92 (1.40***)	1.86 (0.81***)	1.14 (1.51)	1.39 (1.61)
Alternatives Relative to Base case: Additional Regressors						
2.	• Stock Prices (Real Growth)	1.62 (1.61)	1.94 (1.40***)	1.87 (1.23***)	0.97 (1.62)	1.04 (2.37)
3.	• Stock Price Gap (BEAM)	1.74 (1.60***)	1.84 (1.08***)	1.76 (1.37***)	1.54 (0.97***)	1.84 (2.12)
4.	• Stock Price Gap (Filter)	1.66 (1.54***)	1.99 (1.58***)	2.02 (1.00***)	1.15 (1.64)	1.40 (2.45)
5.	• New House Prices (Real Growth)	1.61 (1.54**)	1.37 (1.44)	0.84 (0.55***)	0.63 (0.97)	1.31 (2.06)
6.	• New House Price Gap (Filter)	1.65 (1.45***)	2.15 (1.10***)	2.00 (0.79***)	1.13 (1.94)	1.46 (1.70)
7.	• Stock Prices (Real Growth) • Stock Price Gap (BEAM)	1.70 (1.47***) (1.53***)	1.97 (1.19***) (0.91***)	1.86 (1.13***) (1.14***)	1.36 (1.60) (1.44)	1.40 (2.19) (2.11)
8.	• New House Prices (Real Growth) • New House Price Gap (Filter)	1.64 (1.64) (1.47***)	1.38 (1.38) (1.26***)	1.01 (0.68***) (0.62***)	0.62 (0.96) (2.06)	1.27 (1.90) (1.55)
9.	• New House Prices (Real Growth) • New House Price Gap (Filter) • Stock Prices (Real Growth) • Stock Price Gap (BEAM)	1.65 (1.44***) (1.58**)	1.61 (1.17***) (1.02***)	1.01 (0.70***) (0.60***)	0.59 (1.67) (1.77)	1.44 (1.76) (2.03)
10.	• New House Prices (Real Growth) • Stock Prices (Real Growth)	1.58 (1.59) (1.59)	1.41 (1.54) (1.36**)	1.02 (0.82***) (1.08)	0.60 (1.20) (1.67)	1.38 (2.12) (2.34)

Notes: Each cell presents the RMSE for the linear model and, in parentheses, for the threshold model, for the given model at the specified horizon. * indicates that the RMSE of the threshold model is significantly lower than the RMSE of the linear model at the 10 per cent level; ** at the 5 per cent level; *** at the 1 per cent level.

Table 6: Inflation Root Mean-Squared Errors, Linear vs. Threshold Models

Model	Regressors	$k = 1$	$k = 4$	$k = 8$	$k = 12$	$k = 16$
Base Case						
1.	• Lagged Inflation • Output Gap (QPM)	2.86 (2.23***)	1.32 (1.30)	0.53 (0.65)	0.47 (0.59)	0.58 (1.02)
Alternatives Relative to Base Case: Additional Regressors						
2.	• Stock Prices (Real Growth)	2.96 (2.40***)	1.33 (1.30*)	1.03 (0.53***)	0.87 (0.95)	1.45 (1.31***)
3.	• Stock Price Gap (BEAM)	2.92 (2.63***)	1.30 (1.24**)	0.66 (0.54***)	0.87 (0.81***)	0.77 (1.10)
4.	• Stock Price Gap (Filter)	3.03 (2.43***)	1.35 (1.34)	0.65 (0.57***)	0.50 (0.80)	0.69 (0.84)
5.	• New House Prices (Real Growth)	2.85 (2.34***)	1.50 (1.39***)	0.88 (0.56***)	0.71 (0.78)	2.20 (0.89)
6.	• New House Price Gap (Filter)	2.86 (2.72**)	1.35 (1.20***)	0.58 (0.46***)	0.40 (0.58)	0.32 (1.07)
7.	• Stock Prices (Real Growth) • Stock Price Gap (BEAM)	3.00 (2.30***) (2.62***)	1.31 (1.16***) (1.23***)	1.12 (0.72***) (0.65***)	1.13 (0.95***) (0.88***)	1.49 (1.37***) (1.26***)
8.	• New House Prices (Real Growth) • New House Price Gap (Filter)	2.85 (2.34***) (2.54***)	1.49 (1.29***) (1.10***)	0.78 (0.52***) (0.39***)	0.45 (0.96) (0.60)	0.86 (0.80***) (1.05)
9.	• New House Prices (Real Growth) • New House Price Gap (Filter) • Stock Prices (Real Growth) • Stock Price Gap (BEAM)	3.05 (1.97***) (2.56***)	1.66 (1.00***) (1.10***)	1.03 (0.26***) (0.39***)	0.74 (0.64***) (1.19)	0.55 (0.85) (1.10)
10.	• New House Prices (Real Growth) • Stock Prices (Real Growth)	2.95 (2.32***) (2.54***)	1.51 (1.47*) (1.41***)	0.90 (0.54***) (0.50***)	0.64 (0.82) (0.91)	1.73 (0.85***) (0.82***)

Note: See notes to Table 5.

Table 7: Estimated Parameters for Best Linear and Threshold GDP Growth Model

Model 5, k = 8

Variables	Linear Model	Threshold Model Regime 1: House Price Growth ≤1.931	Threshold Model Regime 2: House Price Growth > 1.931
Constant	2.174 (0.371)	2.354 (0.403)	6.719 (2.579)
Output	0.019 (0.097)	-0.020 (0.092)	0.891 (0.990)
Output Gap	0.002 (0.076)	0.047 (0.077)	-0.443 (0.637)
Term Spread	0.443 (0.106)	0.501 (0.090)	-0.451 (0.721)
House Price Growth	-0.232 (0.054)	-0.204 (0.064)	-1.302 (0.297)
Number of Obs.	78	63	15
R^2	0.396	0.513	

Table 8: Estimated Parameters for Best Linear and Threshold Inflation Model

Model 9, k = 8

Variables	Linear Model	Threshold Model Regime 1: House Price Gap ≤ 0.01188	Threshold Model Regime 2: House Price Gap > 0.01188
Constant	0.968 (0.122)	1.485 (0.12)	0.948 (0.376)
Lagged Inflation	0.518 (0.039)	0.618 (0.037)	0.335 (0.110)
Output Gap	-0.342 (0.048)	-0.470 (0.035)	-0.027 (0.084)
House Price Growth	0.159 (0.019)	0.252 (0.023)	0.241 (0.017)
House Price Gap	12.18 (2.67)	25.27 (2.00)	7.461 (4.658)
Stock Price Growth	0.002 (0.006)	-0.051 (0.009)	0.009 (0.007)
Stock Price Gap	-0.003 (0.007)	-0.015 (0.006)	0.024 (0.011)
Number of Obs.	78	49	29
R^2	0.846	0.952	

Figure 1:

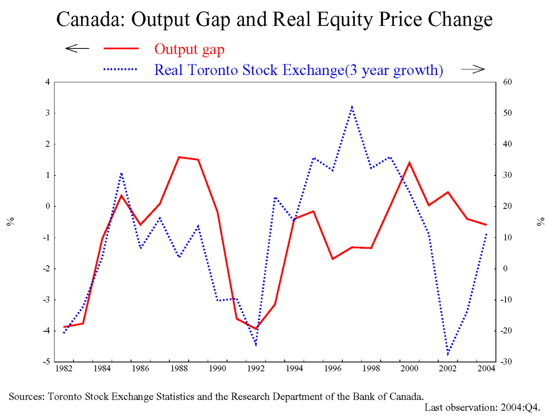


Figure 2:

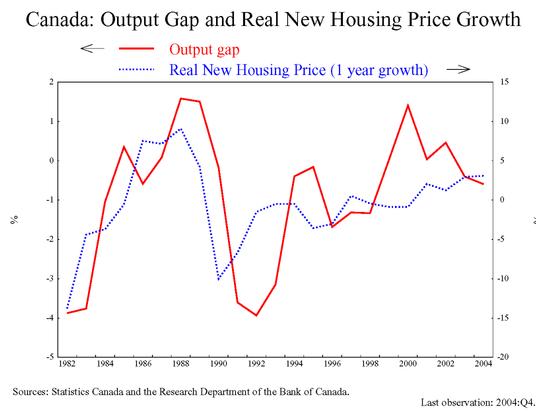


Figure 3:

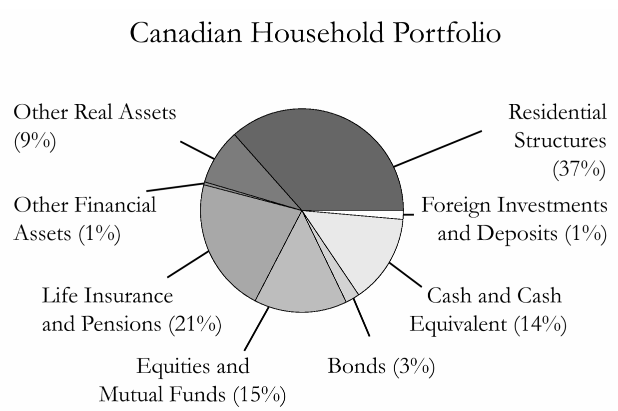


Figure 4:

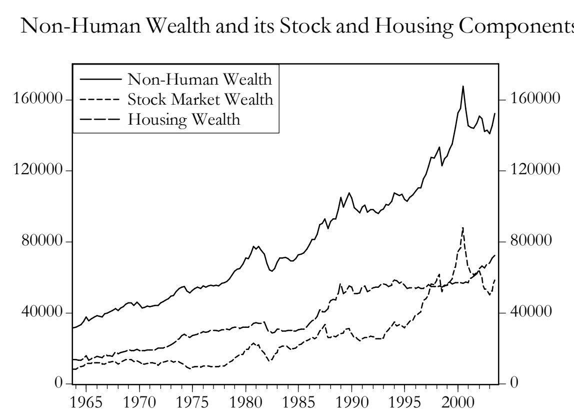
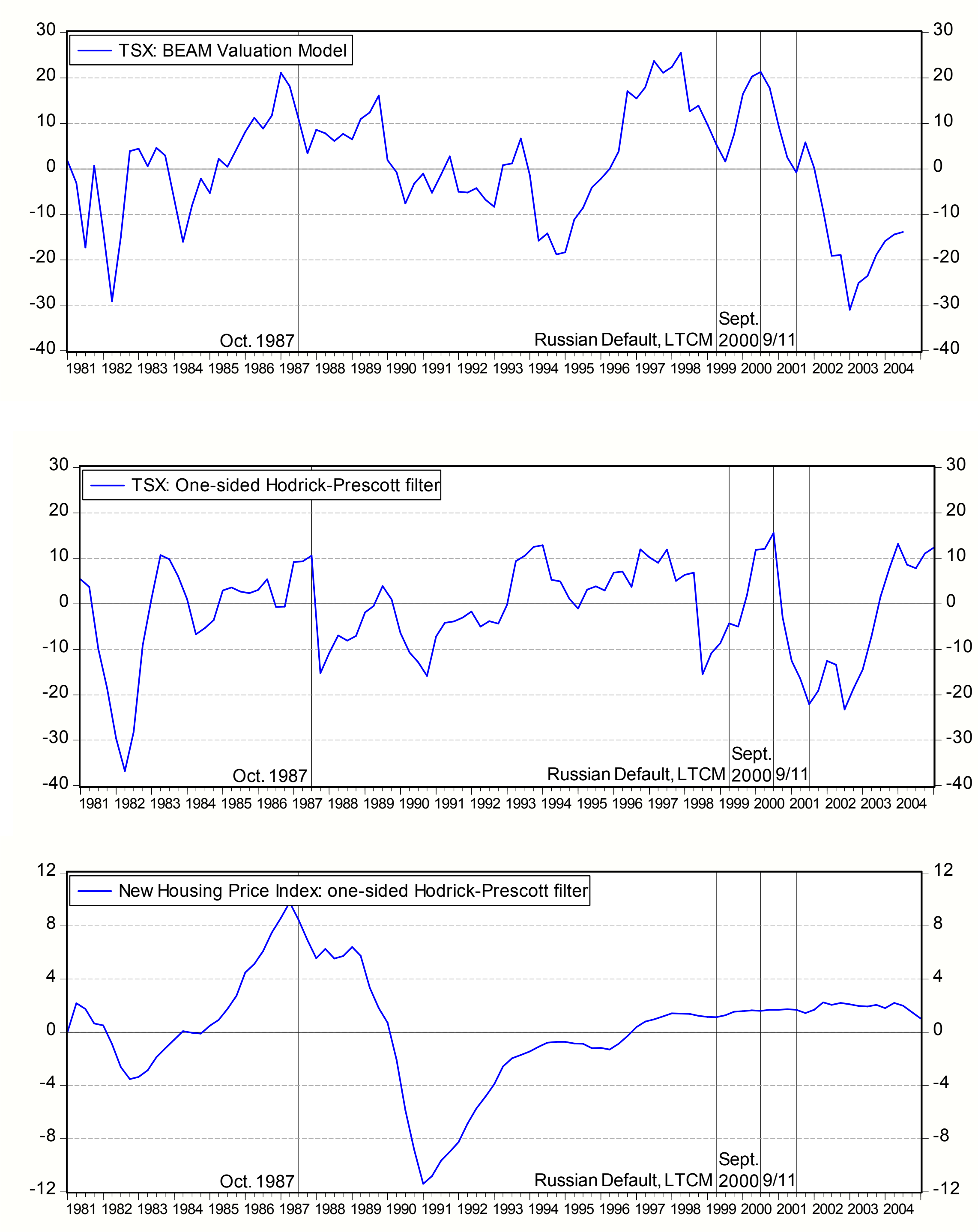


Figure 5: Alternative Measures of Asset-Price Misalignments



Appendix: Gauthier and Li (2004) BEAM measure of equity-price misalignments

Gauthier and Li (2004) define equity-price misalignments as the error-correction term from the cointegration relationship linking the equity market to its long-run determinants (output, inflation, and interest rates). Such a measure indicates how far equity prices are from their fundamental value, but does not tell us which of the equity prices or their fundamentals, or both, would move to close this gap.

In BEAM, the permanent components of every variable are estimated in the vector-error-correction model (including stock prices) using the identification methodology suggested in King, Plosser, Stock, and Watson (1991). This allows the construction of a stock market gap, defined as the difference between stock prices and its permanent component. The gap is therefore the transitory component of the stock market which, by definition, should not last. This way, a negative (positive) gap suggests that stock prices are expected to increase (decrease) in the absence of further shocks.

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